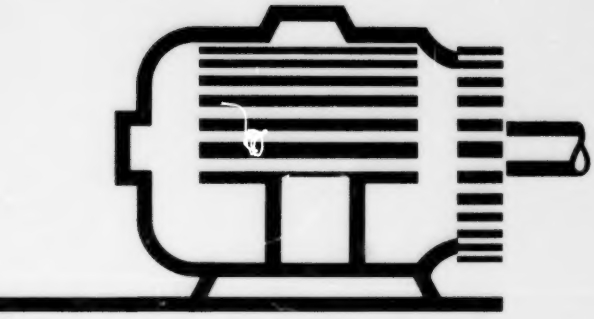

High-Efficiency Motors

POWER SMART

Intelligent Energy Choices

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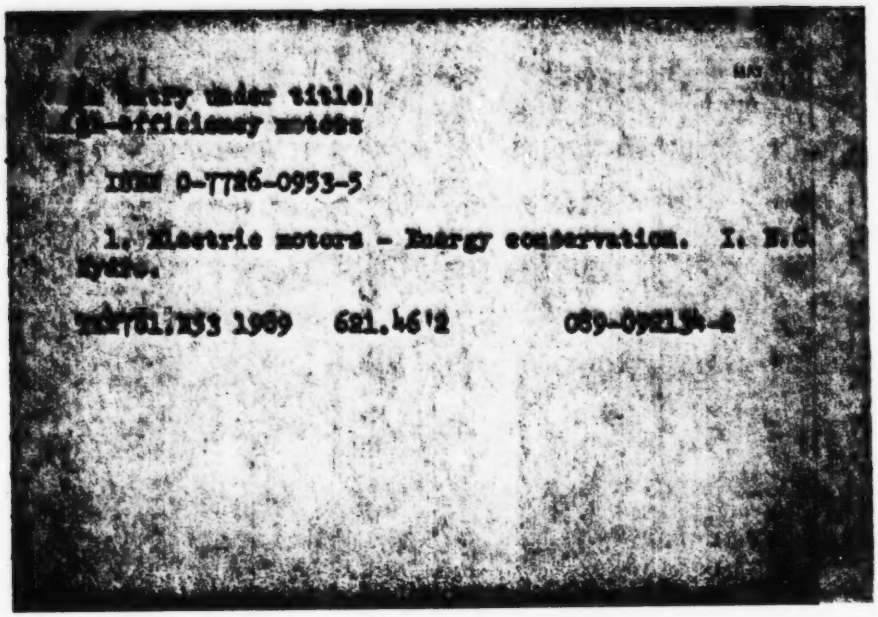

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INTRODUCTION

Using electricity efficiently is a good way to increase profits and stay competitive. Higher efficiency in your operation lowers your power bill today, and helps keep the cost of power down tomorrow by deferring the need to build additional generating capacity. This is why B.C.Hydro has been encouraging the development of newer, more efficient electrical technologies for the past decade.

Over half of the electrical power generated by B.C.Hydro is used by electric motors, most of which are "standard motors". The recent development of new High-Efficiency (HE) Motors makes it possible to improve efficiency by 2% to 10%, with substantial energy savings. If all the motors in B.C. could be instantly replaced by HE motors that were only 2% more efficient, businesses would save a total of $16,000,000 every year.

An electric motor uses, on average, 75 times its initial cost in electricity over its life. This means that when you spend $1,000 to buy a motor, you are making a commitment to spend $75,000. Therefore, you need to consider more than just the initial purchase price of the motor. If you can save 10% on the purchase price of a $1000 standard motor, you will save $100. But if you spend $1000 on an HE Motor that is 10% more efficient, you will save 10% of the $75,000, or $7,500. Looking at it this way, doesn't it make sense that your next motor—new or replacement—should be a High-Efficiency Motor?

This booklet will help you to initiate the upgrading program in your company. It is in three parts:

PART ONE - WHY CHANGE?
PART TWO - CONSIDERATIONS WHEN BUYING HIGH-EFFICIENCY MOTORS
PART THREE - HOW TO OPERATE HIGH-EFFICIENCY MOTORS

Trade up from your standard model and start saving right away.

Advantages of High-Efficiency Motors

The benefits of using High-Efficiency Motors are wide ranging. Reducing operating costs is the most significant advantage, but there are others.

Since the motor is more efficient, it generates less internal heat and may run cooler. By running cooler, the motor should have a longer life.

High-Efficiency Motors often offer an improved power factor, which represents a number of advantages:

- reduction of power factor surcharges
- less loading on feeder circuits and transformers
- reduction of capacitors used for motor power factor correction

Also, because of the extra material in the High-Efficiency Motor, its power factor and efficiency are less sensitive to voltage and loading fluctuations.

Consider High-Efficiency Motors

- for all new installations
- for major modifications of existing installations
- for all new purchases of equipment packages such as air conditioners, coolers, filter systems, etc. that contain electric motors
- when replacing old motors
- instead of reconditioning old (non-High-Efficiency) motors
- when purchasing spare motors
- to replace grossly under-used motors (under 50% loading) that operate at very low efficiency
- as part of your energy management program (if the calculated payback warrants it)
- to take advantage of special rebates, tax allowances, etc. (if applicable)

Find Out More

Get full details from your local B.C.Hydro office or your regional Industrial Marketing Engineer *(see page 26)*.

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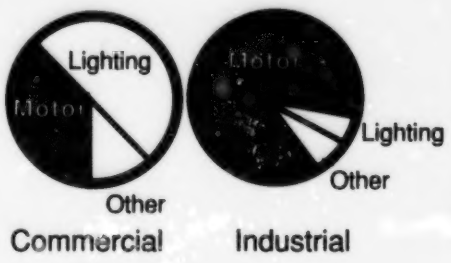
HOW MUCH ELECTRICITY DO ELECTRIC MOTORS USE?

FIGURE 1 Typical Commercial and Industrial Electricity Bill Breakdown



Motors use from five to ten times their purchase price in electrical energy every year. Different businesses use motors in different ways *(see Figure 1)*.

In industrial plants, where motors account for up to 90% of the total electricity bill, they are used to drive:

- processing equipment
- pumps
- compressors
- fans
- conveyors, etc.

In commercial buildings motors are responsible for about 40% of the electric bill and are used for:

- air handling
- refrigeration
- elevators, etc.

Since more than half of the electricity produced in British Columbia is used to drive motors, even small improvements in motor efficiency can lead to substantial savings of electrical energy.

High-Efficiency Motors can be one way of achieving a significant impact on your electrical bill and, more important, on your bottom line.

Savings come in the form of lower energy and demand charges and, in some cases, reduced power factor surcharges. These terms are defined on page 8.

High-Efficiency Motors vs. Standard Motors

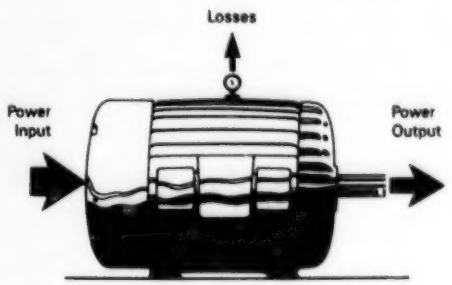
Design changes, better materials and manufacturing improvements make High-Efficiency (HE) Motors more efficient than standard motors by reducing motor losses.

The efficiency of a motor is the ratio of mechanical power output to electrical power input. Mathematically, this is expressed as:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Input - Losses}}{\text{Input}}$$

This is shown below in Figure 2.

FIGURE 2 Motor Losses



Reduced motor losses mean that an HE Motor produces the rated horsepower output with less energy input than a standard motor. Therefore, HE Motors save you money by reducing the energy cost of operating the motor.

Figure 3 compares typical efficiencies of a High-Efficiency Motor and a standard motor.

FIGURE 3 High-Efficiency Motor vs Standard Motor Efficiency

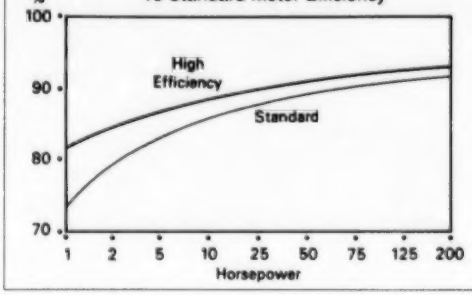


Table I Minimum Motor Efficiencies of HE Motors

HP	High-Efficiency Motors Minimum Efficiency 1800 RPM (%)	1200 RPM (%)
1	80.5	80.0
1.5	80.5	82.0
2	81.5	82.5
3	83.0	84.0
5	85.0	86.0
7.5	87.0	87.0
10	87.0	88.0
15	88.5	89.0
20	90.0	89.0
25	91.0	90.5
30	91.0	91.0
40	91.5	91.5
50	92.5	91.5
60	92.5	92.0
75	93.0	92.5
100	93.0	93.0
125	93.0	93.0
150	93.5	93.5
200	94.0	94.0
250	94.5	94.5
300	95.0	95.0
400	95.0	95.0
500	95.0	95.0

The Minimum Efficiencies in Table I are often exceeded and in some cases a 10% improvement over standard motors can be achieved. Manufacturers will provide the efficiency figures on request. In addition, B.C.Hydro's data base of efficiencies for the most common motors in B.C. is available on request.

Motor Losses and Their Reduction

Core Loss (about 25% of total losses)

Core loss represents the energy required to magnetize the core material (hysteresis) and losses due to the creation of small electric currents that flow in the core (eddy currents).

Hysteresis loss is reduced by using low-loss electrical steels in the core. Eddy current loss is decreased when core laminations are made thinner. Core loss is also reduced by lengthening the core to reduce magnetic density.

Stator Loss (about 35% of total losses)

Stator loss is caused by heating. Resulting from current flow (I) through the resistance (R) of the stator winding, this is commonly referred to as I^2R loss.

Stator loss can be reduced by increasing the stator slot size and by using larger diameter conductors.

Rotor Loss (about 25% of total losses)

Rotor loss is the I^2R loss in the rotor winding. (In squirrel-cage induction motors the winding is actually conductive bars running axially along the rotor and joined at the ends.)

Rotor loss can be reduced by increasing the size of the rotor bars and end rings to give a lower resistance or by reducing the motor load current.

Stray Load Loss (about 10% of total losses)

Stray load losses are the result of leakage flux induced by load current, and vary as the square of load current. These losses are elusive and more difficult to reduce.

Windage and Friction Loss (about 5% of total losses)

This loss represents bearing and air friction against the rotating rotor. Improved bearing and air-flow design can reduce losses somewhat but, more important, when other losses are reduced the cooling requirement is lessened and a smaller fan can be used.

Note that core loss and windage and friction loss remain constant for operation at a given voltage and speed. They are essentially independent of load. Both stray load loss and I^2R losses increase with motor load.

Motor construction changes are limited, and eventually efficiency improvements conflict with other design parameters. The motor designer is then forced to make compromises. For example, as rotor resistance is decreased to reduce losses, inrush current increases and starting torque decreases.

Annual Electricity Savings

The cost of electricity for a commercial or industrial operation is composed of four components:

Basic Charge: a flat monthly amount, the cost of operating your account (meter, meter reading, etc.). It is independent of the amount of electricity used.

Energy Charges: the total electricity used in the period (calculated in kW.h).

Demand Charges: for the highest rate of consumption at any time (calculated in kW).

Power Factor Surcharge: for power factors less than 90%.

Note: for details see B.C.Hydro Electric Tariffs.

High-Efficiency Motors give you lower energy and demand charges and sometimes a lower power factor surcharge. Other benefits include lower operating temperatures and longer motor life.

Model for Calculations

A detailed calculation of annual electricity savings can be made in relation to the above charges. However, except where the motor is not operated at the peak demand time, using an average cost of energy will give equivalent results in all cases.

Before you can calculate the dollar savings, you have to calculate the predicted energy savings.

High-Efficiency Motors need fewer kilowatts input for the same output as standard motors. The difference in efficiency between an HE Motor and a standard motor determines the actual kilowatts saved.

$$\text{kW Saved} = \text{hp} \times 0.746 \times \left(\frac{100}{E_{\text{standard}}} - \frac{100}{E_{\text{HE}}} \right)$$

E = Efficiency

The kW savings are the demand savings. The annual energy savings can then be calculated as follows:

$$\text{kW.h Saved} = \text{kW Saved} \times \text{Annual Operating Hours}$$

You can use this kilowatt-hours saved figure to calculate the dollar savings as shown below.

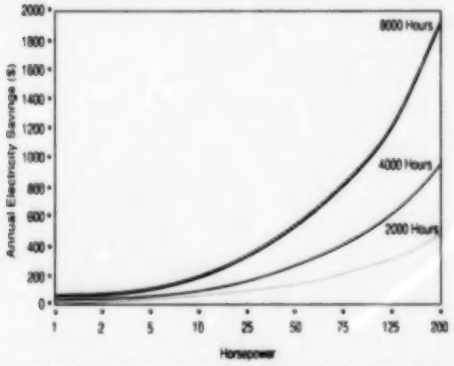
Cost Savings

You can determine your average electricity cost from your past bills or by calling the B.C.Hydro Industrial Marketing Engineer in your region *(see page 26)*.

> Cost Savings =
> Average Electricity Cost x kW.h Saved

Figure 4 shows that your electricity savings will be greater if your motor is larger or if you operate it more hours each year.

FIGURE 4 Annual Electricity Savings



Note: Figure 4 is based on an average energy charge of $0.045/kWh.

Assessing Economic Feasibility

The purchase price of HE Motors is 20% to 30% more than standard motors because of their better design. In most cases, however, the energy savings quickly repay this premium. Assessing the energy savings in relation to the premium will determine the economic feasibility of installing HE Motors.

The most common methods of assessing economic feasibility are:

- Simple Payback
- Complex Payback
- Net Present Value (NPV)
- Internal Rate of Return (IRR)

To illustrate these methods, the following examples compare data for a High-Efficiency Motor and a standard motor.

Detailed Calculations (for a 100 hp motor)

Kilowatts Saved

$$\text{kW Saved} = \text{hp} \times 0.746 \times \left[\frac{100}{E_{\text{standard}}} - \frac{100}{E_{\text{HE}}}\right]$$

$$= 100 \times 0.746 \times \left[\frac{1}{90.9} - \frac{1}{93.5}\right]$$

$$= 2.282 \text{ kW}$$

E = Efficiency

Energy Saved

$$\text{kW.h Saved} = \text{Hours of Operation} \times \text{kW Saved}$$

$$= 4000 \text{ hours} \times 2.282 \text{ kW}$$

$$= 9128 \text{ kW.h}$$

Annual Cost Savings

$$\text{Cost Savings} = \text{kW Saved} \times \text{Average Energy Cost}$$

$$= 9128 \text{ kW.h} \times \$0.045/\text{kW.h}$$

$$= \$411$$

In this example, installing a High-Efficiency Motor means a saving of $411 a year.

Simple Payback

The next step is to compare the savings against the price premium of High-Efficiency Motors.

The simple payback period for the extra investment is the ratio of the price premium to the annual electrical savings.

$$\text{Simple Payback} = \frac{\text{Price Premium}}{\text{Annual Electrical Savings}}$$

In this example, the price premium of the High-Efficiency Motor is $700. Thus the simple payback period would be:

$$\text{Simple Payback} = \frac{\$700.00}{\$411} = 1.7 \text{ years}$$

The extra investment required for this HE Motor would "pay for itself" in 1.7 years or 21 months.

After that, the annual saving of $411 will be contributing to a lower operating cost.

Note: For this same example, if the High-Efficiency Motor were run for 6000 hours as opposed to 4000 hours per year, the payback period drops to 1.2 years or 14 months. This is shown by the graph in Figure 5.

FIGURE 5 Simple Payback vs Hours of Operation

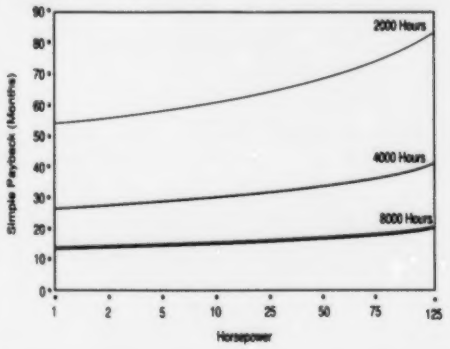


Table II Comparing Payback Data For Different Motor Sizes

Power rating of motor (hp)	1	5	10	25	50	100
Efficiency of standard motor (%)	74.1	81.8	84.1	87.9	89.8	90.9
Efficiency of High-Efficiency Motor (%)	84.0	86.5	90.2	91.7	93.0	93.5
Annual hours of operation	4000	4000	4000	4000	4000	4000
Average energy cost ($/kW.h)	0.045	0.045	0.045	0.045	0.045	0.045
Purchase cost of standard motor ($)	150	250	450	850	1700	4600
Purchase cost of HE Motor ($)	210	350	600	1150	2100	5300
The High-Efficiency Motor comes at a premium of ($) . . .	60	100	150	300	400	700
RESULTS:						
Total annual savings ($)	21	45	108	158	257	411
Simple payback (years)	2.9	2.2	1.4	1.9	1.6	1.7

COMPLEX PAYBACK STUDIES

A simple calculation like the one on page 11 may be all that is required to determine the feasibility of a High-Efficiency Motor within your company's investment criteria. Often, however, more in-depth analysis is required. Net Present Value (NPV) and Internal Rate of Return (IRR) provide a more accurate assessment since the time value of money, as well as tax rates and depreciation, is taken into consideration.

To assist you in calculating your savings, B.C.Hydro has developed a computer analysis program which includes simple payback and NPV. We would be pleased to show you how High-Efficiency Motors can reduce your operating costs.

For information on our computer program to calculate payback, please contact your regional Industrial Marketing Representative or your local B.C.Hydro office.

Table III Typical Hours of Operation (for electric motors)

Hrs/year:	8000	6000	4000	2000	1000
Commercial Installations					
Office Buildings	✓				
Shopping Centres		✓			
Warehouses		✓			
Smaller Installations				✓	
Industrial Installations					
3 Shift (all every day)	✓				
2 Shift (all every day)		✓			
1 Shift (all every day)			✓		
5 days a week, 8 hours per day				✓	
Standby Units					✓
Others					
Hospitals	✓				
Educational Institutions	✓				
Research Institutions	✓				

PART TWO: CONSIDERATIONS WHEN BUYING HIGH-EFFICIENCY MOTORS

When purchasing a motor, the buyer should draw up a performance specification so that the manufacturer can supply the proper motor. Efficiency and quality are usually emphasized in the design of large motors today. However, tradeoffs between various performance parameters can result in decreased motor efficiency if the specification writer is not careful. It is, therefore, most important to specify the desired efficiency at the outset.

The motor purchaser should avoid writing a design-oriented specification that would modify the following basic design elements of the motor:

- frame design
- bearing design
- rotor design
- insulation system

Today's motors have evolved through extensive research and field experience. Deviating from a manufacturer's basic design and safety and industry standards can increase costs and lead to unforeseen problems. Also, the responsibility of the manufacturer to correct such problems would be debatable.

A good specification should spell out:

1. The performance expected from the motor:
   - horsepower and service factor
   - temperature rise and insulation class
   - supply voltage
   - maximum starting current
   - minimum stall time
   - power factor range
   - efficiency range
   - load inertia and number of starts
2. The environment the motor will be operating in:
   - ambient temperature
   - altitude
   - humidity level
   - abrasive or non-abrasive
   - hazardous or non-hazardous
3. The particular protection required as well as any options:
   - thermal protection (with thermostat/thermistor system)
   - space heaters to prevent moisture condensation, if necessary
   - non-standard conduit box location

MOTOR SIZING

For various reasons, most industries use larger motors than necessary. Some of these reasons are:

- insurance against motor failure in critical processes
- ability to increase production
- load fluctuation
- voltage unbalance

Unfortunately, motors are often selected that are either grossly oversized or underloaded for the job. The cost of using a larger motor than necessary quickly adds up:

- higher motor purchase cost
- increased electrical supply equipment cost as a result of an increase in the required kVAR and kVA input due to oversizing
- increased energy costs due to decrease in efficiency
- power factor penalties

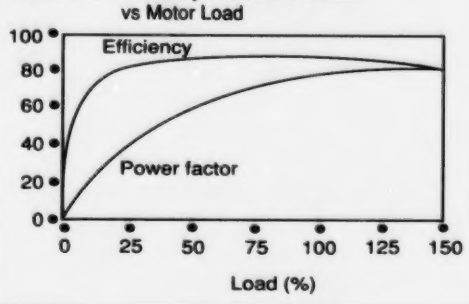
Since induction motors are only available in specific sizes, it is reasonable to operate a motor at 75% to 100% load. For example, if calculations show a load requirement of 35 hp, a 40 hp motor will have to be used, operating at 88% loading. When a motor is used for a non-critical constant load application, such as on a fan, it should be sized as closely as possible to 100% load.

Your High-Efficiency Motor will give you maximum savings if it is properly matched in horsepower to the work that must be performed. This matching will enable you to obtain optimal efficiency and power factor.

Efficiency vs Loading

Most motors are designed by the manufacturer to have a peak efficiency at 75% to 100% loading. Many users, however, apply their electric motors well below this optimum point. When a motor is operated below 75% load, the efficiency drops off considerably *(see Figure 6)*.

FIGURE 6 Efficiency and Power Factor vs Motor Load



Power Factor vs Loading

The power to run a motor has two components: active and reactive power. The active power does the work and the reactive power creates the magnetic forces to turn the motor. Power factor is a ratio of these two powers. A power factor of 50% or less indicates that the reactive power is greater than the active power, and is undesirable.

Power factor decreases as the load of a motor decreases *(see Figure 6)*. This decrease may cause the overall power factor of a facility to drop below 90%, in which case B.C.Hydro will add a surcharge onto the power bill. To avoid this, motors should be loaded as close to 100% as possible to keep the power factor as high as possible. For more information on power factor, ask for our data sheet, *Power Factor*.

Service Factor

Manufacturers have developed motors to accommodate short-term overloads and prevent the need to oversize. These motors are labelled as having a service factor greater than 1.0. They have the ability to operate satisfactorily at the service factor load at a slightly reduced efficiency. For example, a motor labelled with a service factor of 1.15 can operate at 115% load. This overload is handled by using class F insulation.

While standard totally-enclosed motors generally have a service factor of 1.0, all HE Motors have a service factor of at least 1.15 and some have thermal margins as high as 40%. This allows users who deliberately oversize motors to compensate for load fluctuation in order to match the motor size more closely to the load.

Efficiency

A High-Efficiency Motor is specified in the same way as any other motor. Because they both have the same frame size, no special mounting modification is required to replace a standard T-frame motor with a High-Efficiency Motor. HE Motors meet or surpass all EEMAC standard characteristics of current, torque and temperature.

Once other specifications have been satisfied, efficiency should be a determining factor in motor selection. After outlining the basic motor requirements, a purchase specification should always request both the price and efficiency of standard and High-Efficiency models. For both models, efficiencies should be measured in accordance with CSA Standard C390-M1985. This information will allow you to perform a total cost comparison using the economic evaluation method of your choice.

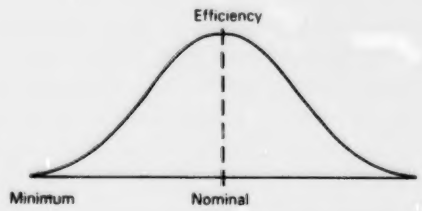
Efficiency Terms

Confusion arises when different terms and standards are used by industry to describe and measure motor efficiency. An understanding of the most common terms and standards will help you to compare different motors when making your selection.

Manufacturers use different methods to achieve improved efficiency. In addition, manufacturing tolerances and variations in raw materials cause different efficiencies from one motor to the next. Therefore, terms defining levels of efficiency have been developed to help you compare one motor with another.

Quoted is the guaranteed efficiency value, within tolerance when tested to CSA-C390.
Nominal, Average Expected or Typical is the average efficiency value of a large number of motors. *(See Figure 7.)*

FIGURE 7 Efficiency Bell Curve



Minimum or Guaranteed is the value all motors should meet or exceed.
Apparent Efficiency equals efficiency times power factor but does not tell you the specific value of either one. Motor selection should not be based on apparent efficiency. Efficiency and power factor should be considered separately.

Recognizing the different terms and making sure you compare like terms will ensure that you select the right motor for your needs. For example, it would be inaccurate to compare one motor's nominal efficiency with another motor's guaranteed efficiency.

Comparing efficiency is further complicated because there are different methods of efficiencies.

Four major standards exist as shown below:

- CSA C390-M1985 Canadian
- NEMA MG1 U.S.A.
- IEC-34.2 International
- JEC-37 Japanese

These standards differ primarily in their treatment of stray load losses. Stray load losses are those losses not accounted for by the sum of windage and friction, stator and rotor I^2R, and core losses. At full load, stray load losses can vary between 0.9% and 5.0% of output depending on the motor design and horsepower rating.

CSA Standard

The Canadian Standards Association (CSA) has developed a standard which accounts for stray load losses and measures them indirectly based on the IEEE method. This standard is more rigorous than the IEEE method because the tester has less room for interpretation error when performing the efficiency test.

Compared with other standards the CSA standard is the most rigorous test with no room for deviations. It provides detailed examples to follow and delivers the most conservative results.

NEMA Standard

The NEMA MG1 standard uses the IEEE Standard 112 Method B which calculates the stray load loss by an indirect process. It provides the second most conservative estimate.

IEC Standard

The IEC standard is not as accurate as the CSA and IEEE standards, which accurately calculate stray load losses. It assumes stray load losses to be fixed at 0.5% of input and also allows a tolerance on the efficiency. This standard is infrequently quoted in North America.

JEC Standard

The JEC standard is the least accurate method and assumes there are no stray load losses. This standard is rarely quoted in North America.

Efficiency Comparisons

It is difficult to compare two motors when their efficiencies are tested to different standards. When obtaining a quote on efficiency, all requests should specify that the CSA C390-M1985 standard be used. If this is not available then the NEMA standard is the next best choice. Using quoted efficiency from CSA and guaranteed efficiency from NEMA will give equivalent results *(see Table IV)*.

Table IV Comparison of typical efficiencies

Standard	Full-load efficiency (%)	
	7.5hp	20hp
CSA C390	**80.3**	**86.9**
NEMA MG-1	80.3	86.9
IEC-34.2	82.3	89.4
JEC-37	85.0	90.4

Enclosure

EEMAC standards describe a variety of different enclosures. Make sure you specify an enclosure that provides adequate protection in your operating environment. If you are unsure, consult your motor supplier. Generally, the more a motor is enclosed, the more expensive it is. High-Efficiency Motors are available in the following enclosures:

Open Drip-Proof (ODP) for clean environments. This enclosure will tolerate dripping liquids no greater than 15 degrees from vertical. Ambient air is drawn through the motor for cooling.

Totally Enclosed Fan Cooled (TEFC) for dusty and corrosive environments. The motor is cooled by an external integral fan.

Totally Enclosed Explosion Proof (TEXP) for flammable environments. This enclosure is able to withstand an internal gas explosion without igniting external gas. The type of gas or dust present must be specified.

Supply Voltage

For motors over 600 volts, efficiency decreases as the specified motor voltage increases for a given rating and speed. Therefore, specifying a motor for a voltage that is high relative to the motor's rating and speed results in an oversized machine with a lower efficiency.

To ensure high efficiency, only large horsepower motors (500 hp and above) should be supplied above 600 volts. Consult your motor supplier for the optimum voltage.

Torque

Torque is a measure of the rotational force that a motor can produce. The physical size of the motor is proportional to its torque, not its horsepower. Therefore, a high torque motor will be larger and may cost more. Induction motors have been standardized according to their torque characteristics (Design A, B, C, D). The design you select must have adequate torque to start the load and to accelerate it up to full speed. Most induction motors are Design B, with Design A being the second most common.

FIGURE 8 Motor Torque Characteristics

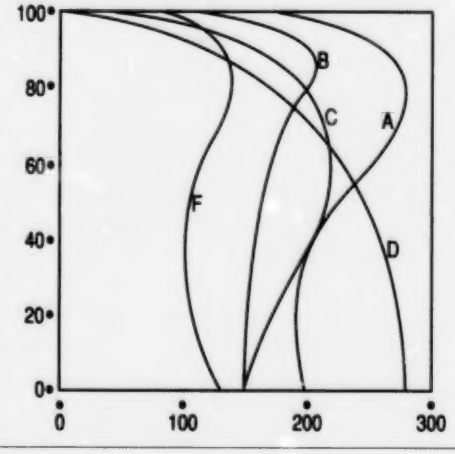


Figure 8 will help you understand the following torque terms:

Starting or Locked-Rotor Torque is the motor starting torque at zero speed. Both Design D and C have a high locked-rotor torque.

Pull-Up Torque is the minimum torque (lowest point on all the curves) developed during acceleration between zero and full load speed.

Breakdown Torque is the maximum torque exerted before stalling. This is shown by the maximum points on the curves. Note that Design D has no breakdown torque.

Full Load Slip refers to the difference at full load between actual running speed and synchronous speed. Notice that the full load slip is greater for Design D than for Design B or C because Design D motors run at a lower percentage of synchronous speed at full load torque.

Each design has its unique characteristics as shown below:

Design	Starting Torque	Starting Current	Full Load Slip	Breakdown Torque
A	medium	high	low	high
B	medium	medium	low	medium
C	high	medium	medium	medium
D	highest	low	highest	high

PART THREE: HOW TO OPERATE HIGH-EFFICIENCY MOTORS

SIMPLE STEPS TO INCREASE MOTOR LIFE

The electric induction motor is a rugged device which, when properly applied, will provide many years of service with a minimum of maintenance. However, simple regular maintenance and inspection of the motor and the electrical system feeding it will increase its life.

Problem Prevention for Your Motor

Since each motor may be a little different, one of the best ways to prevent trouble is to follow the motor manufacturer's maintenance instructions.

In addition, watch for changes in a motor's usual performance.

- Is the motor noisier than usual?
- Is the motor frame temperature higher than normal?
- Does the motor take longer to come up to speed?
- Is there an increase in vibration?

When properly interpreted, these symptoms can help avert serious trouble or motor failure.

Dirt

Dirt can clog screens and filters, reducing air flow and causing the motor to overheat. To prevent this problem, it is important to keep the motor clean. This can be easily done by:

- wiping with lint-free cloths
- using suction to draw out dust
- using compressed air, being careful not to drive dirt further into the motor

Moisture

Although continuous-use motors are not prone to moisture problems, intermittent-use or standby motors may have difficulties. Run the motor for at least a few hours each week to drive off moisture. Be careful that steam and water are not directed into open drip-proof motors. Where totally-enclosed motors are used in a humid environment, remove any condensed water through the drain plug and, if possible, leave the drain plug out. Install space heaters on larger motors.

Lubrication

Over-greasing is the most common cause of bearing failure. Not only does over-greasing actually increase friction, but it can cause the bearing to overheat.

Bearing failure can also be caused by the use of contaminated or improper lubricants.

The motor manufacturer's recommendations should be followed carefully. They will tell you how often the bearings need to be lubricated and the proper type of lubricant to use.

Vibration

A noticeable increase in motor vibration is an indication of trouble. If it occurs, check:

- that all mounting bolts are tight
- the shaft for proper alignment
- for bearings that may need replacing

Identifying the source of vibration can sometimes be difficult. Specialized contractors and consultants can assist you in measuring and analyzing vibration irregularities.

Starting

Excessive starting is a prime cause of motor failure. High starting current generates a lot of heat in the motor. Motors 200 hp and below can only tolerate about 20 seconds of maximum acceleration time with each start. As well, the motor should not exceed more than about 150 start-seconds per day.

For low inertia loads that come up to speed in a fraction of a second, the mechanical stress caused by frequent starting can result in motor failure, even when the total start-seconds remain low. Starting requirements for motors 250 hp and above, as well as severe starting requirements for any motor, should be discussed with the motor manufacturer prior to purchase.

Overload

Overload heaters should be properly sized and installed to protect the motor during starting, overloading and single-phasing.

Note that if you install power factor correction capacitors either on the load side of your motor starter or at the motor terminals, then it is essential to resize your overload heaters.

Problem Prevention for your Electrical System

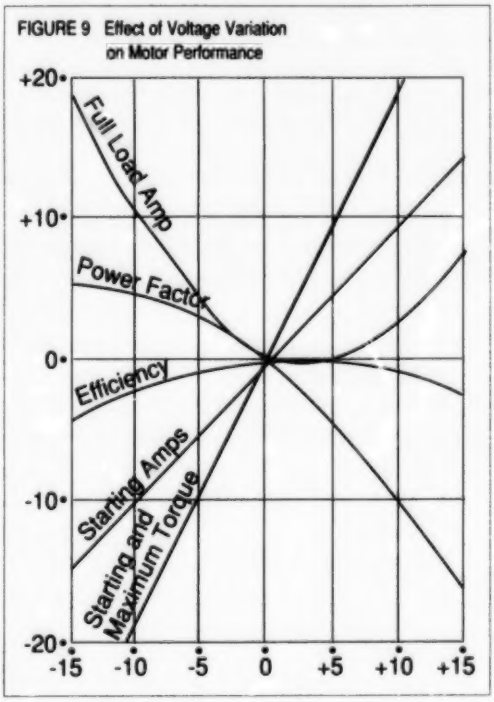
Even a motor in perfect condition can have its efficiency and life reduced by a poorly maintained electrical system. Monitoring voltage is important in preventing problems before they occur.

Voltage Variation

Operating a motor at other than rated voltage can adversely affect performance characteristics. With a 10% increase or decrease from rated voltage, the motor can overheat. Such operation for extended periods of time may accelerate the deterioration of the insulation.

Figure 9 demonstrates the approximate relationships between motor performance characteristics and voltage variation.

FIGURE 9 Effect of Voltage Variation on Motor Performance



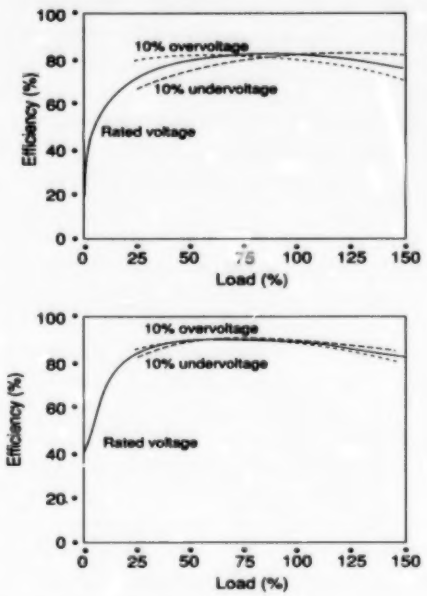
As voltage increases, the full load current increases due to saturation of the iron core. This results in decreased efficiency.

The full load slip decreases with increased voltage.

The starting current, starting torque and breakdown torque all drastically increase with increased voltage.

The improved design and construction of High-Efficiency Motors offer the additional benefit of being less sensitive than standard motors to voltage variation *(see Figure 10)*.

FIGURE 10 Comparison of Voltage Variation on HE and Standard Motors



Correcting Voltage Variation

To prevent reduced efficiency due to low voltage to the motor terminals, it is important to check for excessive voltage drops in the lines feeding the motor. This is the major source of low voltage problems. If the motor is on the end of a long feeder, a voltage drop may be reduced by rearranging the system. System voltage can also be changed by the following three methods:

- Adjust the tap settings on the appropriate transformer. Be sure to follow all safety rules.
- Install automatic tap-changing equipment if the system loads vary considerably over the course of a typical day.
- Install properly sized power factor correction capacitors to raise the system voltage while correcting power factor.

Voltage Unbalance

The previous discussion on voltage variation refers to a balanced three phase voltage. A voltage unbalance occurs due to the unequal application of line voltages to a polyphase induction motor.

This results in a dramatic increase in motor losses and temperature, which decreases the efficiency of the motor and shortens its life. Unbalanced voltage can also cause vibration and bearing failures. It is not recommended to operate a motor with a voltage unbalance above 5%.

Common causes of voltage unbalance are:

- unevenly distributed single phase loads on the same power system
- an open circuit in the primary of the distribution system
- unidentified single phase-to-ground faults

A few simple steps can be taken to ensure a well-balanced system.

- Check your electrical system single-line diagram to see if single phase loads are evenly distributed.
- Regularly check the voltages on each of the three phases to verify that minimum variation exists.
- Check to see if a ground fault indicator should be installed.
- Do an annual thermographic inspection.

When a motor fails, the decision has to be made whether to rewind or replace it. This decision will be influenced by:

- relative cost and availability of rewinding service vs new motor
- age of the motor
- special electrical and mechanical features
- importance of having the motor immediately back in service

Most companies do not have a policy to aid the decision maker. Thus, in trying to get the motor back into service as quickly as possible, the decision maker may overlook motor efficiency and associated dollar savings. Many people do not realize the effect that rewinding can have on efficiency, and as a result are not particularly concerned.

Rewinding may result in lower motor efficiency because of a number of factors. When rewinding the motor, an insulation burnout process removes the original windings. If this process does not take place in special temperature controlled ovens, the insulation between laminations may break down, causing core losses to triple. Damage to the stator or rotor cores, frames, or endshields can also occur. This affects air gap symmetry and increases stray load losses. The type and size of the wire used for the replacement windings, as well as the number of turns, can also affect the efficiency. Of the various motor losses, only windage and friction losses are not affected by rewinding, provided that reasonable care is used in handling the components.

Any increase in losses as a result of rewinding will not only decrease efficiency, but may also cause the motor temperature to increase. This higher motor temperature could cause the rewound motor to fail prematurely.

When you rewind a motor, it is important to exercise care in selecting the right repair shop to perform the task. Some rewind shops guarantee core losses after rewinding.

Avoiding production downtime when motors fail is critical. Considering the following points will help you in selecting the best option in emergency situations.

- keeping a spare motor on hand that could act as a standby for several critical machines. By replacing a failed motor with a spare High-Efficiency Motor, you will avoid the downtime costs necessary to perform the rewind. In addition, you will increase your motor efficiency beyond initial levels and lower your operating costs.
- forming a company policy to replace and not rewind all 20 hp or smaller motors upon failure. High-Efficiency Motors should be considered.
- exercising care in selecting a service/rewind shop, if you decide to rewind your motor, so that it will be done with minimal loss in motor efficiency.

To help you assess the viability of High-Efficiency Motors for your operation, here are answers to typical general information, technical and financial questions.

1. What is a High-Efficiency Motor?
A High-Efficiency Motor produces the same shaft output power (hp), but uses less electrical input power (kW) than a standard efficiency motor.

2. Are all new motors High-Efficiency Motors?
No, you generally have to ask for them.

3. How available are High-Efficiency Motors?
About 15% of motors greater than 1 hp sold in Canada are High-Efficiency Motors.

4. Where can I buy a High-Efficiency Motor?
High-Efficiency Motors can be purchased directly from Canadian and foreign manufacturers as well as from most motor distributors. They can also be specified in any equipment package you may be ordering.

5. How do I know that it is a High-Efficiency Motor?
Compare efficiencies for the same size motor. The High-Efficiency Motor will have an efficiency 2% to 10% greater than the standard motor. Table I on page 6 defines High-Efficiency for 1200 and 1800 RPM three phase motors between 1 to 500 hp.

6. Are High-Efficiency single phase motors available?
Although High-Efficiency single phase motors are not generally available, a few manufacturers are beginning to produce them.

7. Do High-Efficiency Motors require more maintenance?
No. High-Efficiency Motors are equally as reliable as standard motors and have the same maintenance requirements.

8. Can I specify a High-Efficiency Motor as part of an equipment package (an air conditioner, for example)?
Yes. Lower operating costs will offset the added capital cost, usually in less than three years.

9. What HP, speed and voltage ranges are available?
High-Efficiency Motors are available for most motor sizes 1 hp and up at speeds of 3600, 1800, 1200, 900 rpm and three phase voltages of 208, 230, 460, 575 and higher.

10. Can a High-Efficiency Motor replace my present U- or T-frame motor?
Yes. Since T-frame High-Efficiency Motors generally use the same frame casting as a standard motor, standard T-frame to High-Efficiency T-frame should be a straight replacement. However, for a direct-drive application you will need an adapter or transition base for U-frame to High-Efficiency T-frame replacements. In addition, some manufacturers now make HE U-frame motors. Talk to your motor manufacturer for specifics.

11. How do the efficiencies of U-frame motors compare with standard T-frame motors?
Generally speaking, U-frame motor efficiencies are higher than those of standard T-frames. When T-frames were developed, the objective was to reduce motor size, and thus cost. Little emphasis was placed on motor efficiency as electricity was relatively inexpensive.

12. Should I rewind my standard efficiency motor or purchase a High-Efficiency Motor?
A High-Efficiency Motor will result in lower energy costs when compared with a rewound motor. Its cost effectiveness will depend on the hours operated, motor efficiencies, utility rates, and the difference in cost between the rewind and the High-Efficiency Motor.

13. What is the efficiency of a High-Efficiency Motor at different load points?
Greater than for a standard efficiency motor. The efficiency of any motor varies with such factors as size, speed and loading.

14. Do High-Efficiency Motors maintain the same percentage edge over standard motors when the load range drops from full load?
Most manufacturers are designing their High-Efficiency Motors to peak from 75% to 100% load. Generally, efficiency stays fairly constant from full down to 50% load, but the power factor drops quite significantly.

15. How reliable are High-Efficiency Motors?
As reliable as regular or standard efficiency motors. In some cases, they have a longer life because of lower motor operating temperatures.

16. What is the power factor of a High-Efficiency Motor?
Power factor varies depending on loading and manufacturer, but in many cases it may be up to 7% higher than that of a standard motor.

17. I have heard different types of efficiencies quoted. What are they?
The following motor efficiency definitions are used: Quoted, Nominal, Average, Expected, Calculated, Minimum, Guaranteed, and Apparent Efficiency. The most commonly used are Quoted, Nominal and Minimum, defined as:

- Quoted Efficiency is the guaranteed efficiency value, within tolerance when tested to CSA C390.
- Nominal Efficiency is the average measured efficiency of a large number of motors of the same design.
- Minimum Efficiency is the value appearing at the end of the bell curve plotted from the measurement of a large number of motors.

18. What are CSA C390-M1985, IEC 34.2, J EC 37, MG1?
These are motor efficiency test standards:

- CSA C390-M1985 is a Canadian-developed standard and is more rigorous than other test standards. As a result, it generally results in a more conservative rating of efficiency.
- IEC 34.2 is the European motor test standard.
- JEC 37 is the Japanese motor test standard.
- NEMA MG1 has been the most commonly used North American standard and adopts the IEEE Standard 122 Method B.

19. Can I compare motor efficiencies using nameplate data?
Not necessarily. Some nameplates do not carry an efficiency value, and others might state a nominal value. You should always obtain efficiency figures, and the standard used, from the motor manufacturer.

20. How is a High-Efficiency Motor constructed?
High-Efficiency Motors are manufactured using the same frame as a standard T-frame motor, except that they may have:

- higher quality and thinner steel laminations in the stator
- more copper in the windings
- smaller air gap between the rotor and stator
- reduced fan losses
- closer machining tolerances

21. Can a standard motor be rewound as a High-Efficiency Motor?
It is possible for a standard motor to have what is commonly called a "high-efficiency rewind". This rewind procedure can increase the efficiency of a standard motor above its initial level. However, the efficiency would still be lower than that of a new High-Efficiency Motor, because of its unique physical characteristics.

22. Can a High-Efficiency Motor be rewound?
Yes, but special care must be taken when stripping out the old windings to ensure that the high efficiency is maintained after the rewind.

23. Is the service factor any different from that of a standard motor?
Service factor for all HE Motors is at least 1.15 and can be as high as 1.30 to 1.40.

24. How much do High-Efficiency Motors cost?
Generally, 20% to 30% more than standard motors, depending on the specific motor, manufacturer, and market competition. It may, however, be possible to negotiate a lower price premium when purchasing a whole fleet of High-Efficiency Motors.

25 What is the payback period for a High-Efficiency Motor vs a standard motor?
The payback period varies according to the cost difference, hours of operation, electrical rates, motor loading and difference in motor efficiencies. A 25 hp High-Efficiency Motor will have a payback period of less than two years when compared with a standard efficiency motor for 4,000 hours of operation each year. (See page 10 for more details on payback.)

26. Are there any hidden charges?
No. The installation cost for a High-Efficiency Motor is the same as for a standard motor.

27. Where can I get more information on High-Efficiency Motors?
From your motor supplier, electrical contractor or local B.C. marketing representative.

For further information on energy efficiency contact your Regional Industrial Marketing Engineer.

Lower Mainland:
B.C.Hydro
Lower Mainland Divisional Office
4940 Canada Way
Burnaby, B.C. V5G 4K6
(604) 293-7799

Prince George:
B.C. Hydro
Northern Divisional Office
P.O. Box 6400
3333 - 22nd Avenue
Prince George, B.C. V2N 2K4
(604) 561-4894

Vernon:
B.C. Hydro
Southern Interior Divisional Office
1401 Kalamalka Road
Vernon, B.C. V1T 8S4
(604) 545-8111

Victoria:
B.C. Hydro
Vancouver Island Divisional Office
P.O. Box 500
4400 West Saanich Road
Victoria, B.C. V8W 2P2
(604) 479-9311

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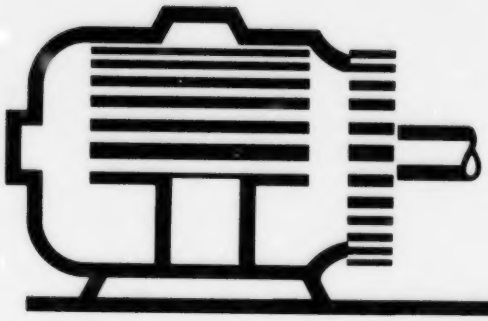

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